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The Chilean nitrate industry

San Francisco, U.S.A.

[1914?]

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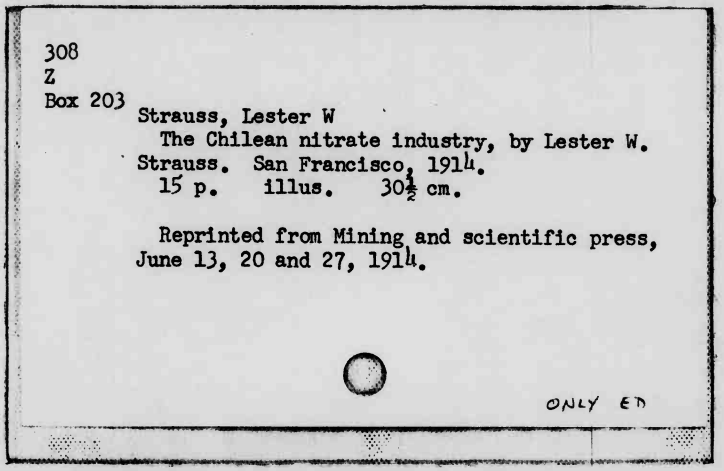

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THE CHILEAN NITRATE INDUSTRY

By LESTER W. STRAUSS

Reprinted from *MINING and Scientific PRESS*
June 13, 20, and 27, 1914.

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U. S. A.

LESTER W. STRAUSS
ENGINEER OF MINES

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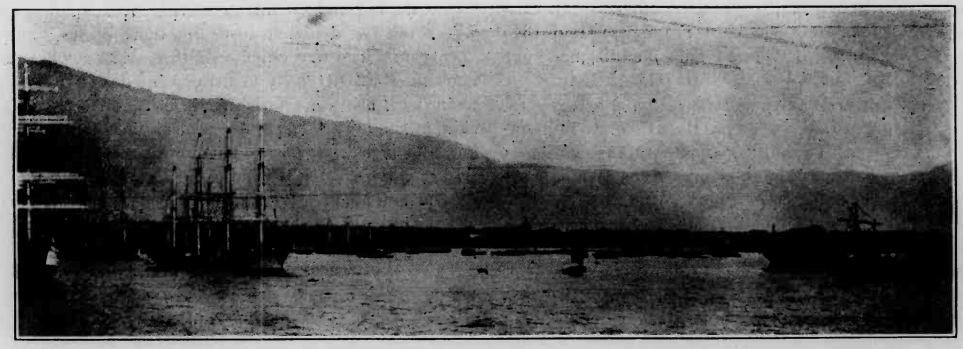


PORT OF IQUIQUE.

The Chilean Nitrate Industry

By Lester W. Strauss

Of the metallic and non-metallic minerals peculiar to the West Coast of South America, nitrate of soda is the most important. It forms the basis of an extensive industry in Chile and contributes 80% of that country's revenue by reason of the export duty imposed. Its uses are more far-reaching and beneficial as a re-invigorator of soil, so largely applied abroad, than to other applications in the arts, of which the manufacture of explosives is an important industry.

Beginning of the Industry

The beginning of the nitrate industry is said to date from 1809, in the province of Tarapaca, through the efforts of Tadeo Haenki; the wonderful results obtained in 1830, in the application of nitrate as a fertilizer, marks the realization of its usefulness and the active commencement of its exploitation. (As the outcome of the war of 1879, Chile came into possession of the fields which had previously been Peruvian and Bolivian territory.) From a yearly output of 22,723 quintals (46 kg. each or 101.4 lb.), in 1812, the industry had grown to 56,214,140 quintals in 1912. An appreciation of the 1912 output, although only 54,197,439 quintals was exported, is better obtained from its intrinsic value to the Chilean government as revenue—£6,323,035 ($31,350,568*); the value of nitrate products was £22,302,956 ($107,054,090); the export duty is 28d. ($0.56) per quintal, but at some future date—in view of increased cost of production, mainly due to scarcity of labor and the decline in grade of the material treated—this tax must be lowered and thus make available much ground now too low grade to permit working under the existing duty, which amounts to one-third of the average selling price. According to figures submitted by the Chilean government, its income from 1891 up to 1913, a period of 22 years, was £84,296,334 (approximately $405,000,000). The increasing consumption of nitrate has had its corresponding effect upon the yearly revenue from the export duty. These increases make the frequent loans of the Government, for railroads, harbors, and sundry essential improvements, a matter of reasonable security—within bounds—as no recourse is had to taxation of the citizens individually. The following figures, totals from 1891 to 1912, inclusive, and the individual years 1891 and 1912, give an idea of the importance of the industry:

	1891.	1912.	Total.
Output:			
Quintals	16,982,931	56,214,140	747,862,160
Metric tons	781,184	2,585,850	34,400,283
Exported:			
Quintals	17,158,971	54,197,439	723,813,593
Metric tons	789,281	2,493,082	33,294,094
World's consumption:			
Quintals	20,960,785	54,990,104	725,862,446
Metric tons	964,158	2,529,545	33,388,335

It is of interest to note that although the output and exportation have more than trebled, consumption has increased less than 2.7 fold during the 22 years; the difference is the necessary stock.

The nitrate industry is confined to the provinces of Tarapaca and Antofagasta in the northern part of Chile (between latitudes 19°30′S. to 26°S.). The latter province is the larger producer. The exporting ports, beginning at the north and proceeding southward, are Pisagua, Junin, Caleta Buena, Iquique, Tocopilla, Mejillones, Antofagasta, Caleta Coloso, and Taltal. Iquique is the most important port. The area of Chile is 757,366 square kilometres (292,343 square miles), of which the provinces of Tarapaca and Antofagasta comprise 46,957 (18,125 square miles) and 120,708 (46,593 square miles) square kilometres, re-

*Throughout this article, figures stated in pounds, shillings, and pence refer to English, and those in dollars refer to United States currency.

spectively; up to the present time 4604 square kilometres (1777 square miles) are controlled by the various nitrate companies (in both provinces), and 1345 square kilometres (519 square miles) additional have been explored, but not sold by the Government.

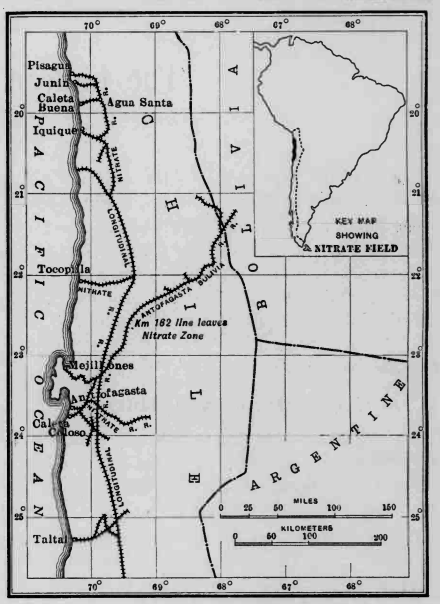
The districts are known as follows: pampa Tarapacá, ports Pisagua, Junin, Caleta Buena, and Iquique; pampa Toco, port Tocopilla; pampa Antofagasta, ports Antofagasta and Mejillones; pampa Agua Blanca, port Caleta Coloso; pampa Taltal, port Taltal.

In 1912 there were 170 *oficinas* (the local name for the nitrate treatment plants) including those in construction, of which 38.5% was Chilean controlled, followed by English (37%), and German companies (15%), the remaining 9.5% is represented by six nations. Only one American company exists, the Du pont Nitrate Co., owned by the E. I. du Pont De Nemours Powder Co., operating in the Taltal district. It operated the Delaware oficina and exported 152,030 qq.* in 1912, equal to 0.28% of the Recently interest has been taken by a new company, American Nitrate Co., at Toco in the Tocopilla district, where title to the ground has been in dispute between Bolivia and Chile. W. R. Grace & Co., of New York, through a subsiduary company—the Nitrate Agencies—represents 9 oficinas; the product is sent to the United States and England. The combined output for 1912 was 3,175,400 qq. (about 5.1 per cent).

The Nitrate Fields

The stretch of territory represented by the 6°30′ of latitude (about 450 miles) concerned is a dry (rain falls during lapses of 15 to 20 years), arid country rising from 2200 to 7500 ft. above sea-level at distances varying from 14 to 20 miles in from the coast. (The oficina Alianza, in Tarapaca, is at 2300 ft. and the oficina Delaware, in Taltal, is 7500 ft. above sea-level.) Between this plateau and the coast is a range sometimes attaining a height of 5000 ft. above sea-level, which barrier rises rather abruptly from the sea and affords only occasional ports. This remarkable topography begins just at Arica, where the coast line turns from a southeast course to almost due south, as one enters Chilean waters from the north. The nitrate fields appear to occupy a north and south trend, thus paralleling the coast line, the nitrate usually lying on the western side of the *pampa* or plateau. The eastern side of the nitrate fields is flanked by the foothills of the Andes, that serve as a huge wall against the rain-bearing winds from the east thus cutting off the possibility of rainfall which would play ruinous damage with the nitrate ground. The cold Humboldt stream of the Pacific Ocean condenses the moisture of the warm western winds into mists which are rarely permitted to precipitate as rain, due to the strong evaporative powers of the sun. In the winter season these dense mists, or fogs, form nightly but are dispersed by the sun after daylight. The slight moisture thus precipitated affords life to some vegetation, but its effects on the nitrate ground is *nil*. It has been stated that there is some relation between the fog and the nitrate as the latter is not found where the fog does not form but there is one known exception. The dry climate of this arid region is remarkable but extremely healthy. The days are hot, at noon, with heavy westerly winds in the afternoon and calm at sundown. The nights are cold but invigorating, and the mornings crisp. An amusing feature of the region is the electrical condition. Combing one's hair, dry, brings about a 'sparking' but pleasant sensation. The electrical phenomenon has been noted to affect surveying where compasses are employed.

The rocks of the region are essentially igneous, forming the coastal range and the Andes already referred to: northward from Agua Santa (Tarapaca) is con-



NITRATE DISTRICT OF CHILE.

siderable limestone and dolomite. The plateau between is said to consist, in part, of Jurassic rocks, covered over with much marine deposit of sand, gravel, and clay; the recent deposits are not of marine origin and the clays appear to be of volcanic origin. Over this lies stratified mud and angular pieces from the denudation of the hills; bedded in the deposition referred to is the nitrate-bearing mixture.

The origin of the nitrate has not been cleared up despite the theories advanced. It may be stated at the outset that the rocks of the surrounding country have not been considered as a possible source. There are several theories existing, but none are supported by conclusive facts.

It has been already observed that static electricity is present, which, acting on the atmosphere, would liberate oxides of nitrogen and these, in contact with

*Quintals.

the moisture of the air, would form nitric acid. The transition to nitrate of soda in the presence of sodium salts, is readily conceived. Ammonium salts, especially ammonium nitrate, are probable products from the effect of electrical discharges on air and water (that is, mist); reacting with sodium salt ammonium nitrate would be converted into nitrate of soda.

F. W. Clarke, in the 'Data of Geochemistry,' Bull. 330 of the United States Geological Survey, makes the following observations:*

Genesis of Nitrates

"Nitrates are commonly formed in soils by the oxidation of organic matter, a process in which nitrifying micro-organisms play an important part. In moist climates these salts remain in the groundwater, are consumed by growing plants, or are washed away; in arid or protected regions they accumulate to a considerable extent. Some nitrates are also derived from atmospheric sources, the acid being formed by electrical discharges and brought down by rain, but their amount is probably only a small portion of the entire product. Wherever organic matter putrefies in contact with alkaline materials, such as lime or wood ashes, nitrates are produced, a process which has been carried on, artificially, in various countries in order to supply the industrial demand for saltpeter. In sheltered places, such as caverns, calcium nitrate is often produced in large quantities, and its formation has commonly been attributed to the nitrification of bat guano. This supposition, however, may not cover all cases, for W. H. Hess claims that nitrates are uniformly distributed over cave floors in Kentucky and Indiana, even in the remote interiors of caverns where no guano exists. (These views have been disputed by H. W. Nichols who regards guano as the chief source of cave nitrates.) . . The deposits of potassium nitrates found in Hungary are traced by C. Ochsenius to the mother liquors of sea water, their potassium chloride being first transformed to carbonate, which latter is then nitrified in the presence of organic substances. In this suggestion the hypothetical element is rather large, although it is plausibly defended. . . .

"No satisfactory explanation of the nitrate beds has been found although many theories have been proposed to account for same. C. Noellner, who assumed a marine origin for the deposits, suggested that their nitrogen might be derived from the decomposition of great masses of sea-weeds; but in this view has not been generally accepted. For example, the beds at Maricunga (Chile) are 3800 metres above sea-level, and 180 miles from the coast, and other localities present similar difficulties of distance and elevation. The plain of Tamarugal (Chile), studied by W. Newton, lies between the coast range and the Andes, 3000 ft. above the sea, and the nitrate beds have peculiarities which seem to preclude either an oceanic origin or a derivation from guano. Here, at least, bromides are absent, and only traces of phosphates can be found. Sea water would yield the former; from guano the latter would remain. Newton regards the nitrates as originally formed by the oxidation of organic matter in alluvial soil. Tropical floods which cover the plain once in every seven or eight years, bring upon it the concentrated fertility of thousand of square miles and sweep the deposits to the landward side of the coast chain where they are mainly found. This is Newton's view, although he admits the possibility that electrically generated atmospheric nitrates may also be present. The same possibility is recognized by Semper and Blanckenhorn, but rejected by A. Muntz, who regards the electrical source as quite inadequate. Muntz accepts an organic origin for the nitrates, and argues that the calcium salt was first formed, as in the ordinary artificial process of nitrification. That compound then reacts with sodium chloride forming calcium chloride and sodium nitrate, a transformation which can be effected experimentally. The same result was also obtained later by A. Gautier, who finds in guano the source of the nitrogen. The reaction is further suggested by the facts that the Chilean nitre is always associated with salt, and that calcium chloride is found in the underground waters of the pampas. Muntz also proved, by direct experiment, that iodides in a nitrifying mixture were oxidized to iodates, and from the absence of phosphates in the nitrate beds he infers that the nitrates have been transported in solution and re-deposited at a distance from the original seat of their formation.

"C. Ochsenius, who has written voluminously on the Chilean nitrates, regards them as derived from the mother liquors of salt deposits in the Andes. These are supposed to flow downward to the plains, their chlorides being partly converted to carbonates by carbonic acid of volcanic origin. The nitrogen is brought as ammoniacal dust from guano beds upon or near the sea coast, the heavier phosphatic particles being left behind. That such dust is carried by the winds is certain; but is it carried in sufficient amounts to account for large nitrate deposits far inland? Another difficulty is suggested by Darapsky, who points out—in his work on Taltal—the comparative scarcity of carbonates in the nitrate regions. Even the waters of the pampas contain little carbonic acid, and among the mineral springs of Chile and Argentine carbonated waters are the exception rather than the rule.

Saline Water Theory

"That the nitrate beds are proximately derived from the evaporation of saline waters is beyond a doubt, but the evidence is strongly against their having a marine origin. The ultimate source of their nitrogen is a more troublesome question and remains, so far, unsolved. The weight of opinion favors a derivation from organic matter, and from this point of view Newton's explanation of the deposits is as satisfactory as any. Explanations of this order. however, are incom-

*Page 205.

plete for they take no account of the remarkable association of boron and nitrogen. Why do borates and ammonia occur together in volcanic waters, or borates and nitrates in the deposits of both Chile and California? This fact, which has already been emphasized, is surely not without significance and it legitimizes the suspicion that the nitrates may be partly derived from volcanic sources. To be sure this is only a suspicion, but it is one which ought not to be left out of account. Hot springs are common in the desert of California and Nevada; they are also found along the volcanic Andean chain; do they contain boron and ammonia as a general rule, or only in sporadic instances? Such waters, collecting in lagoons in the presence of some organic matter and the nitrifying organisms, would yield nitrates, and the latter would be found in the dried residues. A careful examination of all hot springs existing in the vicinity of nitrate beds is needed before one can decide how much weight can be given to this volcanic hypothesis."

Of the above hypotheses the electrical theory has met with more general approval, at least to the extent of being considered-probably-the chief agent. It is worthy of mention that nitrate ground is readily picked out from barren ground, due to its dark appearance as compared with the latter, when inspected in the early morning before the sun's rays have driven off the moisture of the previous night's fog. This phenomenon is due to the hydroscopic property of nitrate, but is not an unfailing indication.

The composition of the *caliche* (the local name for the nitrate-bearing material), as mined, varies from 18 to 65% $NaNO_3$, but the general average is between 20 and 25%. When pure it is found in crystalline masses either white or yellow and rarely pink, the last two conditions being due to iodate of calcium and manganese respectively. As might be expected sodium chloride, sulphates of soda, lime, and magnesia are associated, besides 'earthy material'. Nitrates of calcium and potassium, perchlorate of potash, and iodate of soda occur in small amounts. A better idea of the composition of caliche can be obtained from the following analyses:

	Taltal. Darapsky.			Antofagasta. S. H. Loram.		Tarapaca. Agua Santa.	
	1	2	3	4	5	6	7
Nitrate of soda	31.90	39.400	56.25	25.500	29.350	34.2	43.3
Chloride of soda	8.00	4.180	2.75	41.860	41.710	32.0	30.9
Sulphate of lime	7.00	3.250	....	1.970	3.610	6.3	tr.
Sulphate of magnesia	6.90	3.970	....	5.990	0.610	2.0	...
Sulphate of soda	8.60	.....	34.60	13.750	4.720	8.4	25.3
Chloride of magnesia	...	3.870	....	.....	.....	...	...
Nitrate of potash	...	.....	....	0.545	.....	1.6	...
Perchlorate of potash	...	.....	....	trace	0.180	...	...
Iodate of soda	0.02	0.053	....	0.136	0.104	0.2	...
Moisture	2.40	.....	6.25	2.970	1.330	1.1	...
Insoluble	34.30	45.240	0.01	7.280	17.590	14.0	0.4
	99.12	100.003	99.86	100.001	99.204	99.8	99.9

One of the largest nitrate producers in the province of Tarapaca is the Agua Santa Nitrate & Railway Co., which has been in operation, as a limited liability company, since 1889. Some idea of its importance may be obtained from the total output from the Agua Santa oficina, only, since 1876 (when the steam plant was put in) which is given as 35,000,000 quintals *salitre*, the name for the finished product. Within recent years the annual production of the Company has been at the rate of 1,500,000 quintals. The Company operates a narrow-gage railroad (30 in.), that taps 22 oficinas, including six of the Company proper, and handles about 6,000,000 quintals of nitrate per year. The line begins at Caleta Alta, from which point three incline planes serve the port—Caleta Buena. The railroad was built in 1891 and is at present 148 kilometres (92.5 miles) long as a main line and branches; its maximum grade is 3% (average 1%). At Huara it connects with the Pisagua branch of the Nitrates Railway, Ltd., which starts from Iquique; this line is standard gage. The Agua Santa company's oficinas are, in order of their importance: Agua Santa, Primitiva, Valparaiso, Abra, Elena, Democracia, and Irene. The last was but recently completed. The total production for 1912 was 1,492,205 quintals, of which the Agua Santa plant contributed 548,633 quintals; it stands eighth among the 99 oficinas existing in Tarapaca, and the Company ninth among 73 producers in the industry. The following descriptions of mining and leaching refer to the Agua Santa plant, but the observations made cover the general practice in the industry.

Occurrence and Composition of Caliche

In the Tarapaca fields four horizons are recognized in the exploration work. The surface material, called *chuca*, is loose and crumbly material containing porphyry boulders; this is usually less than one foot thick and on its character is based considerable importance in prospecting work—it carries little or no nitrate. Below this comes the *costra* which is similar to the chuca in appearance but more solid; the cementing constituents are sodium salts of which sodium nitrate often forms a considerable percentage. It runs as high as 25% $NaNO_3$ but 10 to 15% is the average; its thickness varies from a few inches to 15 ft. In appearance it frequently resembles a breccia. Where high grade, that is above 14%, it is being mined. Next comes the caliche, or the cleanest nitrate mineral, which, when pure, is found as crystalline masses either white, yellow, or rarely pink; the usual color of caliche is reddish brown. The average caliche mined varies between 18 and 65% $NaNO_3$, while picked samples run up to nearly 100%; the thickness is from under an inch to 5 ft., the average would be from 1 ft. to 3 ft. The specific gravity is generally taken as 1.5 for calculation purposes (as only 75% of the mineral is considered as likely to be extracted), although the mineral is 2. The underlying (or 4th horizon) layer is known as *coba*, and consists of a brownish colored

earth mixed with sand and gravel. It contains a slight amount—never in commercial quantities—of nitrate. Below the coba is the igneous rock which is found at varying depths, and in the main valleys are marine beds.

The following analyses, given by Semper and Michels, indicate the constituents of the chuca, costra, and coba. Analyses of caliche have already been given:

	Chuca, %.	*Coba, %.*
Silicic acid	46.70	25.05
Iron oxide	2.00	1.64
Aluminum oxide	12.42	7.96
Manganese oxide	0.45	0.65
Calcium oxide	9.26	6.82
Magnesium oxide	2.88	1.92
Potassium	1.02	trace
Sodium	1.99	19.93
Sulphuric acid	13.23	20.09
Nitric acid	1.14	2.49
Carbonic acid	trace	1.75
Phosphoric acid	0.85	0.17
Iodic acid	0.25	0.13
Chlorine	1.24	12.98
Moisture	0.85	0.95
Costra		
Sodium nitrate	14.6	6.1
Sodium chloride	27.2	18.0
Sodium sulphate	...	20.0
Calcium sulphate	3.8	6.8
Magnesium sulphate	7.5	...
Magnesium chloride	0.4	...
Potassium nitrate	1.7	...
Sodium iodide	0.1	...
Insoluble	42.2	52.0
Moisture	2.6	...

It appears that the costra horizon is not always present in the nitrate fields of the southern districts.

In the early days of the industry, only the high-grade caliche was exploited and considerable was lost in the mining. Present day practice is confined to closer work and selection of probable profitable ground regardless of separating caliche from costra where both can be treated commercially.

The method of exploration is systematic and resembles the sampling of gold placer ground except that drilling machines are not employed. The area controlled is divided into squares usually 100 metres to the side, and holes—begun 9 in. in diameter—are sunk with 'jumper' drills to the coba; the chuca being cleared off prior to drilling. The 'jumper' drills are of 1¼ to 1½-in. steel, or iron tipped with steel, and range up to 15 ft. in length. As a rule 10-ft. drills are employed. The holes are made conical in shape, the apex being on the surface. When bottomed a light charge of gun-powder (dynamite when going through hard caliche) is exploded in them and the blasted material brought to the surface. Boys are usually employed to enlarge holes in the coba below the caliche. The sample is carefully picked over, before assay, all the coba being discarded. Data are taken not only as to the thickness of the caliche, but also the character and thickness of the overlying costra and chuca. The drill holes are plotted, with their corresponding caliche contents and thickness, from which results the extent of the nitrate area is obtained. It is usual to assume that between a hole containing commercial caliche and an adjoining barren, or low-grade hole, half of the intervening distance can be allowed to be within the profitable area (the caliche deposition is necessarily of irregular shape and distribution although continuous). The tonnage of caliche is arrived at by multiplying the cubic metres by 2. This gives metric tons. Of this figure 75% is taken as the probable amount that will be extracted in mining. Where the costra is of commercial grade, its tonnage is calculated similarly, except that only 50% is taken as extractable. The full assay values are not used to arrive at an average of the area, deductions being made for losses in treatment. These deductions vary from 30 to 40% of the assay results, depending upon the grade of the caliche and the character of same. The cost of drilling varies from 50 centavos to 2 pesos per foot (11c. to 44c.), according to the nature of the ground and depth of the hole. Churn drills, such as are employed in gold placer ground, or at the 'porphyry' mines, might do the work more rapidly if the material was not of shallow depth as a rule, and possibly cheaper, but the necessity of water, in the work, would be a serious and detrimental factor though the use of compressed air would appear feasible.

Mining Caliche

Mining the caliche consists in first putting down holes similar to the prospecting holes, but with heavier charges of black powder varying from 100 to 1000 lb., according to the nature of the ground to be opened. Dynamite is only employed to break up large blocks of caliche or for sinking shafts. The black powder is home made, from coal 'fines', refuse nitrate, and sulphur. The last was previously brought from Italy or Japan, but is now obtained from the Tacora deposits inside from Arica, Chile. The powder mixture consists of 25 lb. of coal 'fines,' 100 lb. of refuse nitrate, and 25 lb. of sulphur. The cost is about 0.33d. (1c.) per pound of powder. A charge of powder has a heaving or lifting effect, in exploding, thus tending to minimize the making of 'fines.' The blast makes little noise, only a low rumbling effect resembling an earth tremor, and is accompanied by a cloud of dust, sometimes overshadowed by brownish nitrous fumes resulting from the explosion when the powder is wet or badly mixed. Holes, from 10 to 35 ft. between centres and parallel to the working face (and usually at a distance equal to the depth of the caliche ahead of it), are prepared in advance of the face and fired as occasion demands. It is sometimes found practical to lower a boy into the holes to enlarge the opening when the coba has been reached. In such holes black powder has a greater lifting effect when exploded. This method is also used for isolated or thick beds of caliche. A working face is begun by laying out a trench, dug to the top of the coba and

continuing it according to the nature and extent of the costra and caliche; the process of extraction is similar to bench mining. The chuca is cleared off and thrown as far back as possible; the costra, however, is stacked up, somewhat like a pack wall. The larger pieces are broken down with a wedged-shaped piece of iron using a 25-lb. hammer. These pack walls of costra are sent to the leaching plant whenever of commercial grade, that is above 14%. The broken caliche usually consists of pieces easily handled by one man. Where large blocks result block holing, with dynamite, is resorted to. The lump size (the 'fines' being disregarded) is sorted out and piled up on the costra, to be carted away to the nearest loading station. A nitrate field, after exploitation, greatly resembles a battlefield with earthworks erected-minus opposing armies and accessories. Mining is done on contract, that is to say the company prepares and loads the holes after which the contractor takes matters in charge. The prices paid are 2 pesos (say 44c.) per cart load (35 quintals) for costra and up to 20 pesos ($4.40) per cart load for 50 to 60% caliche, according to the difficulty of extraction. There is a sliding scale rate per cart load, based not on the grade of caliche but on the comparative ease of extraction, a higher rate can be afforded for the good quality when difficult to extract. The contractor is paid for his work, not the quality of the caliche.

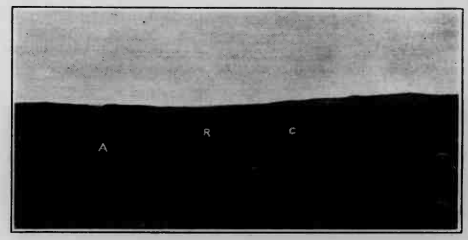
Losses in Mining

The losses in mining caliche are said to vary from 15 to 25%; when costra is taken out for treatment the mining loss is small but the milling loss is great. To the outsider it would appear that crude methods have been employed in mining; these were begun in the commencement of the industry and custom established same as a standard. The introduction of modern methods, particularly the possibility of steam-shovels in mining, has been suggested, but the general argument against a radical change has been the irregularity of the deposits; lack of technical administration is more to the point. In few instances have technical men been put in charge of operations.

Darapsky, in his work '*Das Department Taltal*', mentions calcium nitrates existing in cavities in limestone in the province of Tarapaca. These have been exploited with underground workings to a depth of 40 ft., until non-commercial nitrate was met. The origin is due to "underground water that has passed through the nitrate region and come to rest in a land-locked depression where it evaporates." In the Salar del Carmen in Antofagasta, which, S. H. Loram states to be of the above origin, nitrate crystallizes upon the surface and is worth removing about every four or five years. It has been cited as a case where nitrate grows and has led to a confusion as to its origin.

The caliche is loaded into two-wheeled carts, usually hauled by three mules, at a cost of 30 centavos (6.6c.) per cart. Sometimes sorting over is done, prior to loading, at a cost of 1 peso (22c.) per cart load. The length of haul is generally short, and as a rule over light grades. In general, no attempt is made to load from the ground direct into railroad cars, eliminating cart haul; also, a cart driver never walks alongside but is mounted on the left wheeler. As a rule a man can mine and load from one to two carts per day depending on conditions as well as the individual. Where the ground is mined under difficulties the day's pay is the basis employed.

At the loading station the cart is dumped, the contents falling on an incline platform loading directly to



NITRATE FIELD. A, UNLOADING STATION FOR CARTS; B, RAILROAD LINE; C, CART ROAD.

steel side-discharge, hopper-bottom railroad cars, which hold 7 tons each; these are made up in trains, of six to eight, and hauled by (21-ton) locomotives to the *maquina* or treatment plant. The cars are dumped over bins which have little storage capacity as a plant has a limited number of boiling tanks, and when these are filled no more material is brought in from the 'fields'. From the bins chutes lead to crushers, the caliche (or caliche and costra) being reduced to 2-in. size; rolls are also used, placed below the crushers, but no arrangements are made for screening, so that there is an unnecessary making of 'fines'. The ideal product for leaching is the coarse size (about 2 in. diameter) with a minimum amount of 'fines', as the latter tend to cake in the boiling tanks and prevent thorough percolation of the solutions. The treatment of the fine material, separately, is receiving attention and experiments are under way. The crushed material is hauled up an incline, to the boiling tanks, in a three-ton, side-discharge, hopper-bottom, steel car and automatically released, then moving on a slight down grade parallel to the tanks (locally called *cachuchos*). Each series of tanks are trestled, at right angles to their lengths, by two lines of track (30-in. gage); the loaded car moves on a turntable and is 'spotted' where needed. The tanks, made of ¼-in. or ⅜-in. iron plate, are 9 ft. wide, 24 ft. long, and 7½ to 8 ft. deep, holding approximately 900 quintals (under 45 tons) of caliche. Each tank has a false bottom, of perforated plate with 7/16-in. holes staggered 2 in. apart, that stands 8 in. above the real bottom. Two bottom discharge gates, (each one foot square) serve as discharge for the leached caliche (locally called *ripio*) to 3-ton cars that are run in below the tanks and hauled up an incline to the waste dumps. In the early days of the industry this

contained up to 20% $NaNO_3$; at present the ripio averages from 7 to 10% $NaNO_3$. A series of four turns of 3-in. steam coil passes around the sides, inside of the tank. Through this live steam, at 25-lb. pressure, circulates. The material to be leached is heated up to 90° Twaddell. Mother liquor originally from the crystallizing tanks, containing about 30% $NaNO_3$ and 13% NaCl, is run in over the caliche and left 6 hours in contact from the time steam is turned off. Each tank is connected with its neighbor by means of a siphon, which draws off the solution below the false bottom (called the crinolin plate) and discharges it into its neighbor at a point about two-thirds up the height of the tank. The siphon pipes are so arranged that the liquor must pass diagonally from one end of the tank to the other, and from the top down. The tanks are connected in series of four. Every pipe connection, between the tanks, has a discharge valve for drawing off the solution below the false bottom, and a bottom discharge plug for cleaning out below same. Three other pipe connections exist for admitting cold mother liquor, and wash, and fresh waters.

The present system of treatment, as in vogue since 1876, was introduced by J. T. Humberstone, resident manager for the Agua Santa Nitrate & Railway Co. He adopted the Shank process which had been previously used only in the soda industry. Mr. Humberstone, known in the province of Tarapaca as the 'Father of the nitrate industry', ingeniously modified the Shank system to suit local purposes. In the early days of the industry the boiling tanks were placed over an open fire; in 1856 heating was done by blowing steam into the liquor covering the caliche. This innovation gave higher recoveries at less costs.

The leaching of caliche is based on the fact that sodium nitrate is decidedly more soluble in hot than in cold water, also that, in cooling, the hot saturated solutions(which have been produced in the presence of a large excess of common salt) first precipitate sodium chloride, and upon the further reduction of temperature the salt is re-dissolved, yielding almost pure nitrate of soda. Sulphates, which occur in less percentage, react similarly but because the amount present is less, they do not seriously contaminate the soda. The application of the principle is described in detail below but it is worthy of note at this point that the refined nitrate is crystalized out of hot solutions by cooling, and the cold mother liquor (saturated) is sent back to be mixed with material ready for leaching in the boiling tanks, thus running no nitrate solution to waste. Early in the process considerable salt, from the caliche, goes into solution but later is re-precipitated, as the temperature rises and continues, in the presence of an excess of undissolved nitrate in the caliche. A portion of this nitrate is dissolved, the salt-remaining with the earthy matter-sometimes occurring as white crystalline masses or replacing the nitrate in the caliche and forming a crustation over same. The hot solutions leave the tanks—at a temperature between 80° and 90°C.—and pass through to settling tanks where mud separates out, as also considerable salt due to the drop in temperature to between 60° and 65°C. (the settling takes about two hours). The solution of saturated nitrate then passing to the crystallizing tanks, locally called *bateas*.

Solution of Nitrate

The following table, by M. A. Prieto, shows approximately the solution of nitrate and chloride of sodium from an excess of both salts, in 100 c.c. of water, at varying temperatures:

Temp., ° C.	Nitrate, grams.	Salt, grams.	Density, ° Twaddell.
10	49.50	27.0	72.0
20	57.00	26.0	75.5
30	65.80	24.0	78.5
40	75.50	22.5	82.5
50	86.50	20.5	87.0
60	98.00	18.9	91.5
60 to 65			90 to 95*
70	110.40	17.5	96.0
80	123.80	17.0	100.5
90	139.00	16.2	103.5
100	157.50	16.0	107.5
110	184.00	15.4	108.5
120	220.00	15.0	110.5

*Temperature and density corresponding to the hot solution stated below.

The number of degrees Twaddell multiplied by 5 plus 1000 equals the specific gravity, water being 1000.

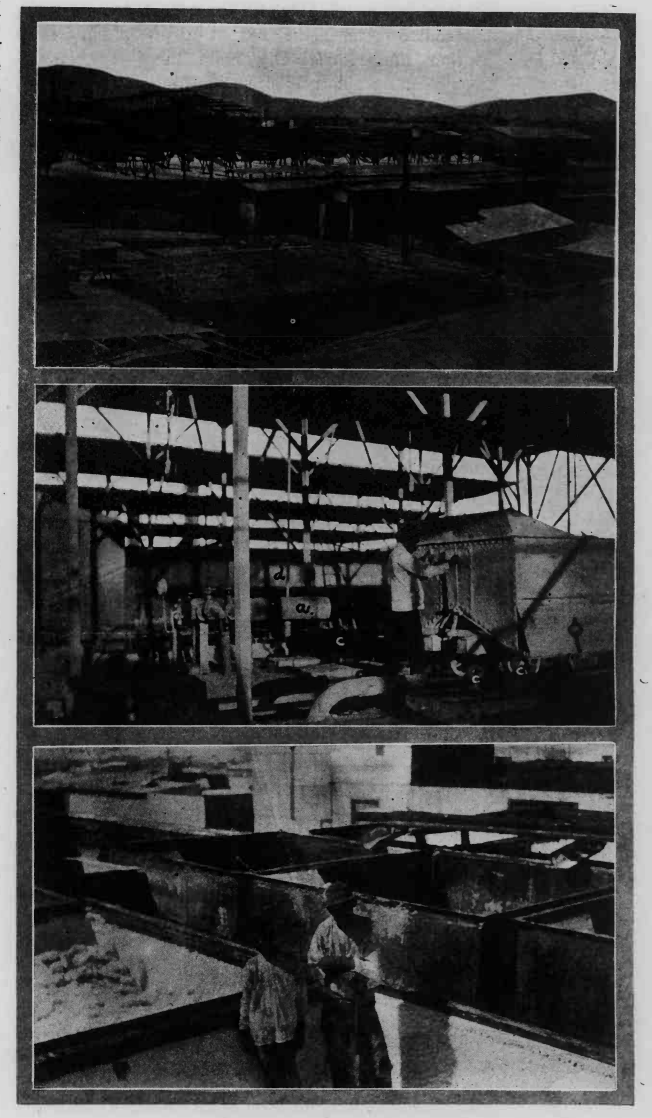
Every charge of caliche is given four boilings, with solutions each successively weaker than the previous one admitted, and one fresh-water wash. Thus each mother liquor goes through four boilings with material successively higher in nitrate, finally reaching the desired density varying from 90° to 95° Twaddell; the density desired depends on the quality of the caliche leached and the quality of the salitre or nitrate, 95% (minimum) $NaNO_3$, to be made. High density means cleaner nitrate but with increasing costs due to the raising of more steam; the economical limit of the density raising determines this point. The calculation of the water to be used in leaching is an important economic consideration; too much water means that an excess of fuel must be consumed—too little water leaves part of the caliche undissolved. The average specific gravity of the hot saturated liquor, or *caldo*, for the settling tank, is 1.50, while the mother liquor, leaving the crystallizing tank, is 1.41 (82° Twaddell).

For a clear conception of the process it will be assumed that tank No. 5 has been charged with caliche and steam has been turned on. Mother liquor, already through three boilings, is admitted at the top and boiling proceeds until the density limit, the economical point, is reached. The contents of the tank are allowed to settle a few minutes, after the steam has been shut off; the solution (caldo or saturated liquor) is then drawn off from below the false bottom and goes to the settling tanks. The perforated false bottom serves not only as a space for settling out the fine mud,

or slime, but as an equalizer for the circulation of solution through the caliche. The fine mud is sometimes treated separately for its nitrate contents. Tank No. 6, in which second stage liquor is boiling with twice boiled caliche, is then ready to have its siphon—to tank No. 5—opened, the liquor discharging over the top of No. 5. Meanwhile, the other two siphons of the series are opened up and a solution of weaker density enters the top of the tank while the higher one leaves through the bottom. Tank No. 8 is being filled with mother liquor pumped back from the crystallizing tanks, and warm wash water, as quickly as the solution is leaving for tank No. 7. When the liquor in No. 5 reaches the minimum economic density, due to solution from No. 6, the circulation of solutions is stopped and boiling again started. Due to the four different densities the solutions will not be at the same level in the four tanks, so that pumping is frequently necessary to help the siphons. When boiling has continued for some time, the liquor in tank No. 5, now thrice boiled, is passed to tank No. 1, the caliche in this being ready for its first boil. Tank No. 8 has now been washed with cold water to cool down the leached caliche and to remove whatever nitrate remains in the mass, which is shoveled out through the two discharge gates; this residue (*ripio*) still carries between 7 and 10% $NaNO_3$. At a later day this low-grade residue, or tailing, may be re-treated when the high-grade caliche and costra have been mined and the export tax reduced. The cold wash water is collected in a sump to be used, at the next transfer of solutions, in tank No. 7.

Time Required for Leaching

The total time taken for a charged tank, from the first operations until the final discard of the residue, is usually 27 hours. The saturated liquor goes to settling tanks, as already mentioned. The sediment, in these tanks, is said to carry up to 40% $NaNO_3$; this is sometimes washed, but more frequently discarded. The crystallizing tanks, of sheet iron, are 18 ft. square, with an inclined bottom so that the depth is 27 in. at one end and 33 in. on the opposite. A tank holds about 600 cu. ft. of solution or approximately 30 tons. A tank is never filled to the brim. From five to ten days are allowed for the cooling and crystallizing of the nitrate, which forms in friable crystalline cakes—about 8 in. thick—on the bottom and sides of the tank. At the expiration of this time the mother liquor is drawn off and pumped back to a boiling tank in which the material has had its third boil. The crystallized nitrate is shoveled into cars, and run on a trestle to be dumped on the drying floor, later—when dry—to be shoveled into 100-kg. sacks (220.46 lb.). The nitrate, now refined, is referred to as salitre in the trade and contains between 95 and 96% $NaNO_3$. The remaining percentage (4 to 5%) consists of chlorides, sulphates,



VIEWS OF A NITRATE OFICINA.

INTENTIONAL SECOND EXPOSURE

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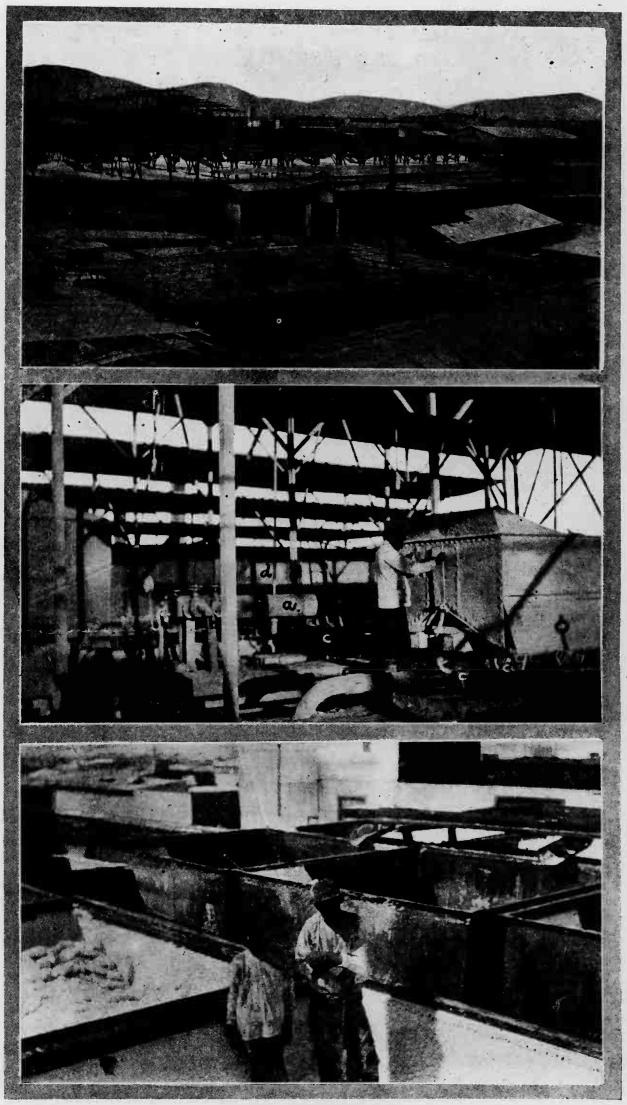


VIEWS OF A NITRATE OFICINA.

the material has had its third boil. The crystallized nitrate is shoveled into cars, and run on a trestle to be dumped on the drying floor, later—when dry—to be shoveled into 100-kg. sacks (220.46 lb.). The nitrate, now refined, is referred to as salitre in the trade and contains between 95 and 96% $NaNO_3$. The remaining percentage (4 to 5%) consists of chlorides, sulphates,

and moisture. Nitrate under 95% $NaNO_3$ content is penalized according to the amount below this figure. While apparently a simple process the average recovery of nitrate from caliche is only slightly above 60% and from costra the recovery is lower. There are no losses due to evaporation, and only a small amount in handling solutions, but the heaviest losses are those resulting from the unleached caliche, that has been crusted over by salt, and to a lesser degree the nitrate in the sediment below the crinolin and in the settling tanks.

The following analyses give an idea of the constituents of the various solutions, also salitre:

	Solution to settling tanks.		Solution to crystallizing tanks.		Sol'n 'mother liquor' to boiling tanks.		Salitre, %.	
Degrees Twaddell:	90	100	92	102	82	86		
	grams per litre							
Total nitrates as nitrate of soda	680	900	700	920	460	537	94.9	96.2
" chlorides "	260	150	190	140	160	150	2.0	0.9
Perchlorate of potash	15	2	...	...	15	2	...	...
Iodate of soda	6	4	...	...	6	4	...	...
Total sulphates	70	52	...	...	70	52	0.6	0.4
Insolubles	...	...	...	...	...	...	0.2	0.1
Moisture	419	392	...	...	699	685	2.3	2.5
Total	1450	1500	...	...	1410	1430	100.0	100.0

In the Agua Santa plant, from which source the above analyses have been obtained, there are 32 boiling tanks, 6 settling tanks, and 192 crystallizing tanks. 900 tons (metric) of caliche can be treated in 20 tanks per day, yielding an average production of 1300 quintals of salitre per day (40,000 quintals per month).

Method of Analysis

The method of analyzing caliche is rapid after experience in the work has been had. Five grams of finely pulverized sample is boiled in 100 c.c. of water, filtered, and the filtrate made up to 100 c.c. Of this 20 c.c. is taken, to which 10 c.c. of sulphuric acid (50° Baumé) is added, and the solution heated in a porcelain evaporating dish to between 70° and 80°C., this temperature is maintained, the solution being stirred with a thermometer, and titration made with a 12% ferrous sulphate solution, acidulated with sulphuric acid. A dark brown coloration is produced which disappears on stirring but leaves a sage green tint to the solution, that deepens as titration proceeds. Effervescence is noticed as the titration approaches completion; the end point is reached when further addition of ferrous sulphate ceases to produce the brown coloration. Practice is necessary to note the end point; the method is correct to within 2%, which is near enough for practical purposes. In a few of the modern plants the method is checked periodically with more exact determinations. In the finished product for export, the nitrate content is estimated by difference; export salitre must contain 95% $NaNO_3$ and the so-called refined, which is really only selected, 96% $NaNO_3$ and less than 1% NaCl (and a minimum perchlorate of potash). The 'nitrate—by—difference' method has been found to yield high results (almost 3%) in $NaNO_3$. The 'Devarda' method, with modifications, gives more satisfactory results; this involves the direct analysis for $NaNO_3$.

Operations in Agua Santa begin at 4 a. m. and continue to 4 p. m. No work is done at night, but the treatment plant operates on Sundays. The steam plant consists of nine boilers—Lancashire type—of which 5 or 6 are in use all the time, for heating the solutions, the caliche, and making distilled water for local consumption and the locomotives. No drinking water is close at hand as that used for the solutions is too saline. The source of this water is from the pampas near an old river course, which at intervals of seven to eight years becomes a roaring torrent due to cloud bursts near its head. Ordinarily the course is dry, so that wells, 40 to 80 ft. deep, must be sunk to reach the underground water. The pipe-line to the treatment plant or *maquina* may be over 6 miles long; electric pumps are used. The feed water to the boilers is preheated by the waste steam from the coils; condensed water, from the heating coils, after leaving the boiling tanks passes through a steam trap. At some plants water is piped (occasionally, as in Antofagasta, over 100 miles) from sources in the Andes.

Output of Individual Plants

The output of individual plants varies from 200 to 8000 tons of salitre per month. The largest oficina, or plant, is the Alianza in Tarapaca, which produced over 1,680,000 quintals in 1912, with a greater output still possible. There were 9 plants which yielded over 1,000,000 quintals each, in 1911, as compared with 11 in 1912. The smallest output recorded was 11,000 quintals (1912). Prior to March 1909, there was a restriction of output regulated by the Nitrate Combination; restriction has been again effected by the producers.

With the larger producing companies steel structures, as well as modern mechanical appliances, prevail; a side view of a treatment plant resembles a multiplane flying machine. The buildings are not housed-in, only terraced roofing of split bamboo cane being used as a protection against the glare and heat of the sun. The average cost of a nitrate treatment plant, exclusive of the cost of the ground and associated expenditures pertinent to operations, also the promotion expenses,

etc., is approximately £1 ($4.80) per quintal of salitre capacity per month; including necessary accessory equipment such as light, tools, railway cars, carts, mules, etc., the cost is about £1 10s. ($7.20). The total capital invested in the industry, inclusive of equipment (also eight railways) might be £30,000,000 or $144,000,000.

The fuel used in the industry is principally coal, brought from England or Australia in ships or steamers, which return with nitrate; within recent years the use of petroleum has met with much favor. The California crude oil and residuum, the specific gravity varying from 14° to 16° Baumé (0.960 to 0.972 specific gravity), is brought in large tank steamers to Pisagua, Junin, Iquique, Tocopilla, Antofagasta, and Taltal and pumped, through submerged piping, to huge tanks on shore; it is then distributed, in tank cars, to the various plants. The cost placed at the boilers is about $15 per ton of 2240 lb. Coal would cost from $12 to $14 at the same point, per ton. The Peruvian crude oil, specific gravity 0.860, or deprived of its benzine specific gravity 0.881, is landed, at all the above mentioned ports in small quantities for use in Diesel engines which are coming into general use for generating power. The Agua Santa company was the first to use petroleum (in 1903), importing through the port of Caleta Buena Peruvian oil for its own use, and that of the plants served by the railroad (Agua Santa). This Company now employs it for all purposes as fuel for its several plants. The present cost is slightly higher than the California residuum. At Caleta Buena the oil is pumped to the shore tanks through a floating hose, and again pumped to the railroad station on top of the cliff, 2440 ft. vertically, through 7000 ft. of steel piping; a double line, each being 3 in. diameter. Powerful electric pumps, made in the United States, work very smoothly against the 1200-lb. pressure. In all 60,000 tons of oil is handled at Caleta Buena per year and the consumption is increasing.

Power Plant at Agua Santa

The power plant at Agua Santa, which (inclusive of the boiler consumption) consumes about 450 tons of oil per month, consists of three sets (one in reserve) of three-cylinder Diesel engines, each of 120 hp. Each engine is belt-connected with a 100-kw. Westinghouse dynamo, which furnishes the necessary power for the treatment plant, or máquina, and electric lights about the entire plant. The crushers, there are six of the Blake type, have 24 by 17-in. openings and are driven by two 40-hp. motors; the six pairs of rolls, 36 in. diameter, are driven by two 20-hp. motors. Electric winches are used to haul the caliche to the boiling tank and the leached material, or ripio to the waste dump. Electric power costs 1d. (2c.) per horse-power hour ($14.40 per horse-power hour per month). The installation of Diesel engines and the electric equipment, replacing a poorly equipped steam plant, have resulted in a reduction of 93% of the former power costs. Coal, delivered on board at Caleta Buena, costs 29s. ($6.96) per 2240 lb. The following figures, in pence per quintal (46 kg. or 101.4 lb.) of salitre, may be taken as representative on the basis of 27,000 tons of material in treatment per month (30 days) resulting in an output of 40,000 quintals of salitre for a Tarapaca plant (average figures for 1912), and 22% caliche treated resulting in 100,000 quintals of salitre being produced, per month, in the Antofagasta plant. Costs have gone up considerably, at least 6d. per quintal, in 1913 due to increased cost of labor and lower recovery.

	Tarapaca. (pence)	Antofagasta. (pence)
Mining or quarrying caliche	10.50	7.632
Transport in carts to loading station	5.10	6.363
Transport on railroad to máquina	2.25	
Crushing material and filling boiler tanks	1.42	.....
Water (cost of bringing same to the works)	1.17	1.156
Leaching (of this, fuel is 5.04d.)	11.41	.....
Treatment	....	12.622
Administration house expenses	1.31	.....
Power (Diesel engines)	....	1.114
General charges including administration	3.00	0.841
Per quintal on *cancha* (drying-floor)	36.16	29.728
Sacks, sacking, and loading on cars	2.62	3.300
Railroad freight to Caleta Buena and loading into lighters	5.50	.....
Railroad freight (150 km.), etc	....	6.600
Lighterage in Caleta Buena bay	0.72	.....
Lighterage [illegible] Antofagasta	....	0.700
Port charges (including propaganda)	....	3.000
Commissions abroad, etc	1.32	.....
Export duty	28.00	28.000
Total	74.30	71.348
Less store profits	1.60	1.001
Total, including propaganda contribution	72.70	70.347

Ocean freight is 1s. 3d. per quintal; previously it was under one shilling.

It is evident from the above that the export tax is a heavy charge. In view of the high-grade deposits having become history, a rational reduction of this tax would mean the possibility of increased activities in the treatment of low-grade caliche and costra. (In 1903 the average grade of caliche treated was 26% $NaNO_3$; in 1912 it was 18%—this refers to the entire industry.) More economical methods might be evolved and larger tonnages treated, with resultant lower costs, but it is questionable as to how the market would absorb the increased output. A lower cost would tend to eliminate the entry of the artificially made (Norwegian) nitrate, and by reason of a lower selling price consumption on a larger scale might be induced where present prices are prohibitive. The prevailing number of oficinas cannot produce salitre f.o.b. at less than 7s. ($1.68) per quintal (60d. is probably a minimum figure) so that a low price abroad would reduce production, notwithstanding that the largest oficinas have been planned to effect low costs, and possibly demoralize the Norweigan nitrate making. This latter industry, it is stated, will soon be in the position to develop 500,000 hp., hydro-electrically, and produce 6,600,000 quin-

tals of calcium and sodium nitrates per annum. In 1912, 1,304,400 quintals—an apparently low output—was produced. The total proposed would be less than one-eighth of the Chilean production for 1912. Its effect on the Chilean product would not be serious in view of the latter's yearly increases. The Norwegian nitrate cannot be shipped great distances. The local demand exceeds the supply hence there is no necessity for long transportation, and must be produced close to the point of demand as it is more hydroscopic than the Chilean nitrate and readily becomes a pasty mass. It cannot be handled in sacks and is packed in wooden barrels wrapped in strong paper.*

The following figures of comparison between salitre and the two most important artificially made fertilizers are of interest:

	Nitrogen, %.	Ratio of cost per unit of nitrogen.
Ammonium sulphate	20.5	1.07
Salitre (Chilean nitrate)	15.5	1.00
Norwegian (calcium nitrate)	13.0	1.15

The Southern Chemical Co., at Nitrolee, South Carolina, may produce calcium nitrate, using the Paulin process, at the rate of 50,000 quintals per annum.

Agua Santa Railroad

The Agua Santa railroad serves 16 oficinas besides the six of the Company, not including the one just completed, the Irene. The locomotives, which are of the Baldwin type, haul a train usually made up of 20 cars, each carrying on an average of 5.5 tons (metric), or 55 bags, of salitre. The line has an almost continuous down grade from Agua Santa to Caleta Alta; the ride in the coach, at the end of a train, with the frequent sharp curves to negotiate, is a memorable one producing all the inward distress of seasickness. Alongside of the track is a 3-in. pipe carrying distilled water for the locomotives. About 865,000 gallons of distilled water and 500 tons of coal are consumed monthly by the locomotives. At Caleta Alta are well equipped machine and repair shops, roundhouse, etc., also storage tanks for petroleum. Telegraph and telephone lines supplement the equipment. A sufficiently large rolling stock is always kept on hand. The locomotives are 21 tons and are run in a series of five or six trains at intervals of from 500 to 1000 ft. The loaded nitrate cars are switched to the head of an incline upon arrival at Caleta Alta, and hooked singly to a one-inch cable, which is controlled by a specially designed drum and brake in the head house. The wear on the cable is severe, although passing over rollers; its average life is 300 days. The vertical descent is 2440 ft. to the pier at Caleta Buena, the track varying from 22 to 32° pitch. There are three inclines, each double tracked (30-in. gage), divided into three divisions of about 800 ft. vertical lift each, and from 1440 ft. to 2340 ft. long on the incline. A down trip, including hooking and unhooking at the two intermediate stations also at the head and foot of the incline, takes approximately five minutes; the actual descending time is less than half of this. In an average day's run (of 11 working hours) 120 loaded cars are handled; a record run of 250 cars has been made. The cost of handling is 1s. (24c.) per ton. The up cars are loaded with supplies.

The sacks are sampled in the yard, which is a shed of considerable extent so as to permit the proper sorting out of the various companies' products, by a government official, who also keeps track of the shipments made. A narrow scoop, similar to a cheese tester, is inserted in every bag and the resulting sample reduced and divided into three bottles which are duly sealed. Each company receives its respective sample, one is kept by the official, and the third is held for umpire. Nitrate under 95% $NaNO_3$ is penalized according to the lack of $NaNO_3$; 1% of the price being deducted if under 95% and over 94%, 3% additional if under 94% and over 93%, and so on with increasing penalty; nitrate above 95% $NaNO_3$ is contracted for to contain more than 96% nitrate, 'double refined', and less than 1% salt impurities. This quality generally brings 3d. to 4d. more per quintal than the 95% grade, but the penalty for non-fulfilment is much higher than for the 95% material. The sacks are loaded into launches, by means of chutes, and taken alongside of the receiving ship—usually a sailing vessel—at a cost of 0.72d. (or 1.44c.) per quintal. The loading capacity at Caleta Buena is about 2000 tons per day, when three or four steamers or sailing ships are loading at one time.

Freight Rates

Frequently the incoming boats bring coal from England or Australia, so that low freight rates prevail and competition is keen for the outgoing nitrate freight, which is 27s. ($6.48) per ton, and [redacted] formerly 20s. ($4.80). In 1912, 642,800 tons of coal and 206,362 tons of oil were consumed in the entire industry. Chilean coal is much lower in calorific quality than the foreign coal and none is used in the nitrate industry. Notwithstanding that more than a million tons is produced annually, it is necessary to import over one and a half million tons to supply the consumption of the railroads, steamers, and industries. Petroleum is brought from northern Peru in tank steamers, which discharge to the 6000-ton shore tanks through a 6-in. pipe-line, with flexible joints, that is supported by floats. The specific gravity of the oil varies from 0.861 to 0.884. A ton of 2240 lb. is usually figured as 305 gal., but this depends on the specific gravity. About 5000 tons of petroleum is received per month at Caleta Buena at a contract price on board, which is variable, but 40s. ($9.60) per ton might be

*This statement appears contradictory. Later information not obtained from the quarterly reports of the Nitrate Propaganda Association is as follows: "Norwegian nitrate carries an excess of lime and is not deliquescent or only slightly so. It is packed into tins for transport. As a fertilizer it has the advantage of leaving lime in the soil, which is an advantage in clayey soils."

an average. The cost of unloading is 5 centavos Chilean (1 cent U. S.) per quintal. From the tanks the oil is pumped to Caleta Alta, as already explained, at a cost of 2 pesos Chilean (40c.) per ton, delivered in the upper tanks (2c. per 101.4 lb.). A distilling and ice plant forms part of the Company's equipment in the port. Water is sold at two centavos Chilean (less than half a cent U. S.) per gallon for local use and Caleta Alta, and alongside of ships at 6 centavos Chilean (slightly over 1c. U. S.) per gallon.

The labor question on the nitrate fields has been a serious factor in the production of salitre. Shortage of labor means less output and higher wages, and causes less effort on the part of those employed. The men employed are Chileans, Bolivians, and Peruvians. About 54,000 peones are required in the industry. In 1912, 47,800 were employed, averaging 54 tons salitre per man per year. There is a continual movement, or migration, of the men; within the past two years practically all of the Peruvians (only found in the province of Tarapaca) have returned to their native soil—a result of misguided persecution. The Bolivians are returning to their homes lured by the increasing wages in the tin mines. The Chileans (from southern Chile), obtained in the *enganching* system (hiring through advancements made in wages), are attracted by the higher wage which prevails on the nitrate fields as compared with that at home. As the railroad construction (especially the Longitudinal railroad) is practically finished, more men should be available. The rate of wages varies from 5 pesos ($1.10) to 7 pesos ($1.54) per day.

The laborer is brought to the province and his fare is paid. On the field he can hire himself out wherever he chooses; no deduction is made from his wages to pay expenses and no contract is made. The expenses of his family are also paid and every inducement is made to keep him from returning southward. The enganching organization has a fund of 200,000 pesos ($44,000) cash invested in advances.

The Nitrate Propagation Association (Asociación Salitrera de Propaganda) was formed in Iquique (and later, 1896, legalized by Congress), as a separate organization from the combination of the several nitrate companies, to limit production and sustain prices. These limitation endeavors, started in 1884, were in general disastrous as prices fluctuated beyond their control. The Association keeps statistics in which are recorded the transfer of properties, names of new properties, sales and changes of oficinas, besides the figures of production, exportation, and consumption of salitre, record of the meetings held and all information for the good of the cause, especially the progress made in the consumption of the artificially made fertilizers, and advertises the benefits of its products abroad. Offices have been opened in the principal nitrate consuming countries, and considerable activity is displayed in this propaganda.

The board is composed of seven members from the Tarapaca fields, two from Tocopilla, three from Antofagasta, and two from the Taltal districts. The Association is sustained by the income resulting from the 3/8d. (3/4c.) collected per quintal exported. This was originally 1/8d. (1/4c.). Due to excessive production, large stocks abroad, speculations, and the fact that a detrimental amount of perchlorate of potash (so harmful to vegetation) was found in some of the salitre, the price fell to 4s.6 1/8d., in April 1898. This was record bottom price and caused the worst panic ever experienced in the industry. Two later attempts to sustain prices failed severely, so that at present the Nitrate Propogation Association directorate manages the combination, whose upkeep is sustained by another 1/8d. charged per quintal exported.

Production Statistics

According to the quarterly circular of the Asociación Salitrera de Propaganda, there were 158 oficinas registered in 1911, of which only 111 exported, these shipping 53,250,327 quintals. In 1912 there were 170 oficinas, but only 126 exported, these shipping 54,197,439 quintals. The exports from the various ports for 1911 and 1912 are given below in quintals.

	1911.	1912.	Oficinas 1912. Total.	Producing.
Pisagua	2,917,881	2,391,282	...	...
Junin	1,806,961	1,806,961	...	...
Caleta Buena	5,693,165	5,543,030	...	...
Iquique	11,831,273	12,993,761	...	...
Total from Tarapaca	22,249,280	22,724,223	99	74
Tocopilla	7,440,189	6,188,023	10	10
Mejillones	7,694,606	7,539,235	29	21
Antofagasta	6,759,701	8,119,096		
Caleta Coloso	3,125,436	3,130,773	14	8
Taltal	5,981,115	6,496,099	18	13
Total from Antofagasta	31,001,047	31,473,223	170	126
Total exported	53,250,327	54,197,439		

Nitrate ground is not obtainable by the usual methods of denouncement. Every year certain areas are advertised for sale, by auction, at a minimum bid price of a certain number of centavos [of the gold peso of 18d. (36c.)] per quintal (metric) of salitre producible, the highest bidder obtains the tract offered. The ground has been previously reported on by government engineers, who state a minimum production of a certain number of million (metric) quintals of salitre possible. With this as a basis, and taking into consideration the economic situation of the property as regards railroad facilities and more especially water supply, the price per metric quintal of salitre recoverable is arrived at. The yearly auctions are limited to properties not having a greater total output than 14,000,000 metric quintals (that is, 220.46 lb. each) of nitrate, and to be made up in lots of over 7,000,000 quintals 'output capacity'; where the ground does not permit of this minimum, less may be offered. The transfer of title is under the responsibility of the state.

Entry to the bidding must be accompanied by a deposit, to the order of the Director of the Treasury, for an amount equal to 10% of the minimum price. This deposit is presumably returned to the non-successful bidders. The deeds of sale must be signed within 30 days after the day of sale, and the balance of the sale price then paid in first-class 90 days drafts on London; failure to appear within the time specified, or if the time set is ignored, means the forfeiture of the deposit. The state does not hold itself responsible for the quantity of nitrate said to exist in the ground on the statement, and plans, of the Delegación Fiscal de Salitreras. The date of the auction is published in the newspapers of Santiago, Valparaiso, and Iquique, and abroad in London, New York, Paris, Berlin, and Hamburg. The Government donates money, from time to time, for works beneficial to the industry. For example, it gave 3,800,000 pesos of 18d. gold, or $1,378,000, for a water line for Iquique, and grants a subsidy to the Nitrate Association (begun in 1906 with £30,000) of £40,000 yearly, which will probably be increased to £50,000 in view of the heavy expenses incurred by the Association abroad. It has been stated that the Government has received as revenue, from the export tax, more than three-fold the amount distributed as dividends to the various nitrate companies, but has contributed less than one-third of the money spent in propaganda. In 1912 the contribution per quintal exported (46 kg.) was raised from $\frac{5}{16}$ to $\frac{3}{8}$d. (about £85,000 being received in 1912 from the salitre exported); but this increase (between £14,000 to £15,000) is still insufficient to permit extending the propaganda on the scale deemed advisable and necessary. The total amount contributed by the industry from 1891 to 1913 is stated as £730,727 13s.3d.; the Government has contributed £354,726 7s.4d. during the same period. It is interesting to note the comparison, for 1910, of the sum spent for propaganda by the Potash Syndicate and that for the Salitreras account:

	Value.	Propaganda.
Potash Syndicate	£ 5,000,000	£150,000
Salitreras	22,500,000	100,000

Ammonium Sulphate Competition

With respect to ammonium sulphate, the prices, based on the unit of nitrogen, are practically equal, nitrate being slightly cheaper, but the difference in the amounts of propaganda money spent is considerable. In 1911 salitre averaged £9 17s.11d. per ton and ammonium sulphate £13 15s.3d. The Nitrate Association is straining every effort to keep out competition from ammonium sulphate, its most important rival, and the other artificial nitrogen products, including the calcium nitrate made in Norway. In endeavoring to centralize the selling, and to keep prices fairly fixed, the Association is displaying a financial foresight which must bring about gratifying results.

The well arranged and amply tabulated statistics, issued tri-monthly, show practically every country on the globe a consumer of salitre. Below are given the principal consuming countries, in order of their respective consumption of Chilean salitre for 1911 and 1912, (in quintals):

	1911.	1912.
Germany	16,154,100	19,816,650
United States:		
East coast	11,147,963	8,388,000
West coast	1,116,552	1,195,811
France	7,359,975	7,703,550
Belgium	6,601,050	6,732,225
Holland	3,143,250	3,931,425
England	2,007,000	2,196,450
Italy	1,165,050	967,950
Scotland	881,550	789,525
Spain	195,075	294,525
Austro-Hungary	114,750	154,575
Denmark	74,700	104,850
Sweden	51,525	112,950
	50,093,440	52,388,486
Other countries	2,011,093	2,550,151
Chile	76,944	51,467
Total	52,181,477	54,990,104
Stock on hand (in the various foreign ports)	36,823,212	35,204,913

American Consumption

The United States agricultural industry is said to consume over $150,000,000 of fertilizing material annually. Voorhes has stated that its yearly consumption of nitrate might reach 2,000,000 tons (metric) (43,500,000 quintals, 46 kg.) if 10 lb. was used per acre of ground cultivatable. This appears a low estimate of the amount actually required per acre.

The highest price that nitrate sold for, on the coast, was 9s.6d. ($2.28) per quintal; the low mark (in 1898) was 4s.6⅛d. ($1.08). The average for December 1913 was 7s.11.78d. ($1.92). The quotations refer to duty paid, immediate delivery alongside ship.

The approximate life of the nitrate fields has been estimated with wide ranges of possible existence. Several years ago, 20 to 50 years, allowing for increasing consumption, was suggested, but this is too low an estimate. Later critics (in 1907) suggested 88 years for the supply known to exist at that time, not allowing for a large area that was predicted to exist but not yet discovered. Investigations made by government engineers, of known and prospected ground, give the following quantities, in quintals of 46 kg.:

Tarapaca	725,300,000
Toco (Tocopilla)	614,925,000
Antofagasta	714,184,000
Aguas Blancas	1,083,032,000
Taltal	2,087,603,000
Chañaral and Copiapo	183,700,000
Total	5,408,744,000

Nearly 249,000,000 metric tons.

The present tonnage has also been estimated in the

	Metric tons.
Province of Tarapaca	35,000,000
Province of Antofagasta	185,000,000
Total	220,000,000

Making allowance for a yearly increase of consumption of 1,000,000 quintals (46 kg.), the above figures indicate 60 years as the probable life. It must be noted that there are several factors which would augment the life of the industry, and therefore make the present day prognostications doubtful figures. Reduction of the 28d. export tax would render available much ground that cannot be opened up under the existing duty, which is a heavy item in the selling cost; if the Centralization Committee can effect a fixed price agreement, or if higher prices prevail, ground of doubtful value might be exploited and thus additional area thrown open. Improvement of the present working methods, as regards mining and treatment, would make additional tracts, at present too low grade, available. The tonnage tied up in abandoned workings, and old tailing, or residue dumps, naturally falls into the latter category. There is no doubt that any or all of the above changes can be reasonably effected and in turn result in prolonged life to the industry. These innovations will come soon. The nitrate business is in a transition stage, and the next two years will see marked changes. Considerable experimenting is being done in treatment schemes to increase extraction and lower expenses.

There is good reason to believe that the industry has not reached its maximum; it will naturally be affected by rise and fall in prices, as without a combination among the producers, it is the low-cost producing oficinas that must survive, by reason of large production, with the fluctuating selling prices.

Average Prices

Approximate half-yearly average prices for immediate delivery of salitre (alongside), duty paid, per quintal (101.4 lb.) are as follows:

	First six months:			Second six months:		
	s.	d.	$	s.	d.	$
1900	4	11¼	1.19	5	6	1.32
1901	6	¾	1.46	6	7¼	1.59
1902	6	7	1.58	6	5¾	1.56
1903	6	5	1.54	6	11¼	1.66
1904	6	9¼	1.63	7	10	1.88
1905	7	6½	1.81	7	8	1.84
1906	7	11¼	1.91	8	10	2.12
1907	8	7	2.06	8	8	2.08
1908	7	10¼	1.89	7	6	1.80
1909	6	10⅜	1.65	6	9⅝	1.64
1910	6	6¾	1.58	7	1⅛	1.70
1911	7	1⅜	1.71	7	6⅝	1.81
1912	7	6⅛	1.81	8	6⅛	2.04
1913	8	¾	1.94	7	9½	1.87

The average selling price in London for 1912 was 10.014s. ($2.40); the sea freights fluctuated from 19s. in January to 29.75s. in October; the average for the year was 26.27s. per ton ($6.30).

The foregoing descriptions have been based on notes taken in November 1909 at Agua Santa, and the generous information given and suggestions made by J. T. Humberstone, resident manager at Agua Santa, also data supplied by A. F. Syers-Jones, resident manager in Iquique, and C. C. Aitken, manager at Caleta Buena, of the Agua Santa Nitrate & Railway Co.; also private communications and suggestions from S. H. Loram, of Valparaiso. The tri-monthly circulars of the Nitrate Association Propaganda have been freely drawn upon for the statistical data and general information of the industry. The works of Samper and Michels (1903), later (in 1907) translated into Spanish by Gandarillos and Chigliotti, and Darapsky's 'Das Department Taltal' form excellent reference books on the subject.

The annual statistics for 1912, published by the Bureau Central de Estadistica, states that the value of the metallic and non-metallic production in the country was 372,667,774 pesos of 18d. ($134,158,599). The value of the nitrate produced was 297,372,750 pesos of 18d. ($107,054,190), which represented nearly 80% of the total valuation given. The Chilean peso (paper) fluctuated rapidly. In 1913 the exchange varied from (high) 10.2d. in January to (low) 9.27d. in November; the average was 9.78d. ($0.196). It has been taken at 11d. in this paper. A pound (£1) has been taken equal to $4.80.

In August 1913 there was a movement on to restrict production and thus prevent a further drop in the low price (7s.6d. alongside, $1.80, duty paid, immediate delivery). This step had been suggested so as to bring about better prices. The rate of production for the first six months had been equivalent to 60,000,000 quintals per year. A restriction of 10%, which was then decided upon, was expected to bring up the selling price the desired 6d. per quintal. In fact the price came up 5.78d. It would seem feasible, on the part of the Government, to arrange a sliding scale for the export tax (below 28d. when prices are below a certain quotation, and continuing in a decreasing proportion as prices decline) that would give the producers more margin when prices abroad make operating expenses show a loss. In 1913, from January 1, prices declined from 8s.3d. to 7s.6.67d. in July, then rising but suffering a decline in November. The average for December was 7s.7.78d. In view of the competition with the artificial fertilizers it behooves the Government to exert considerable effort to aid the propaganda, so that Chilean salitre can retain its present position in the world's products.

The following figures are of interesting comparison, the figures being in quintals.

	January to July		For the year July 1, 1912 to June 30, 1913.
	1912.	1913.	
Production	26,856,455	30,092,777	59,450,462
Exported	22,627,094	26,922,030	58,492,375
World's consumption	38,432,229	38,389,687	54,947,562
	Per quintal		
Average price	7s. 6⅛d. ($1.81)	8s. 0¾d. ($1.94)	

The above shows that the consumption for the trading year (July 1, 1912, to June 30, 1913, inclusive) was slightly over 3,500,000 quintals less than the export, and 4,500,000 quintals less than the production. These figures indicate the urgent need of restricting the output.

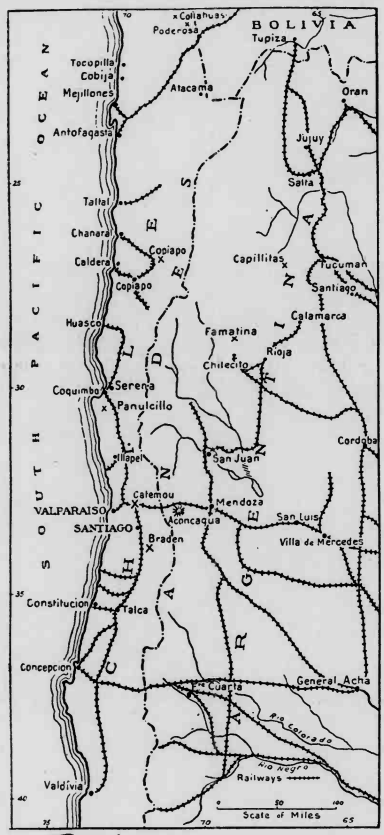
For 1913 the figures were as below. The importance of the restriction of output is brought out by them even more emphatically.

	1913 (calendar year). Quintals.	Metric tons.
Production	60,249,865	2,771,400
Exported	59,529,121	2,738,200
World's consumption	55,562,219	2,555,800

Compared with 1912, the following table is of interest, figures being in quintals:

	1912.	1913.	Increase.
Production	56,214,140	60,249,865	4,035,725
Exported	54,197,439	59,529,121	5,331,682
World's consumption	54,990,104	55,562,219	572,115

The total nitrate produced from 1809 to 1914, in round figures, might have been 48,500,000 metric tons.



Partial MAP OF CHILE.

Iodine to the extent of 1,010,186 lb. was produced and all exported in 1912; it is a product derived from the nitrate and is an additional source of revenue to the Government, the export tax being 10.4d. (21c.) per pound. Its exportation is limited by the 'Iodine Combination' to keep up prices, so only a small proportion of the possible output is made. Those oficinas (40 in 1912) which have caliche high in sodium iodate are the favored producers. The Domeyko oficina in the Antofagasta district has a capacity of 400,000 lb. of iodine per year. The method of manufacture consists in treating the mother liquors from the nitrate crystallizing vats or tanks, which contain iodine principally as sodium iodate, with a mixture of sodium bisulphite, and is carried out as follows: the bisulphite of soda is prepared by burning a mixture of nitrate of soda and coal 'fines,' the soda so formed is leached out, decanted, and sulphurous acid gas (made by burning native sulphur in iron stoves) is passed through in excess, thus forming bi-sulphite. To a given quantity of mother liquor a sufficient amount of the above mixture of bisulphite of soda is added until the temporary brandy coloration (due to free iodine) has disappeared, and the solution is clear, then about 20% of its volume of fresh mother liquor is added through which the iodine is precipitated, the required proportions being determined by tests made beforehand. The iodine is allowed to settle, is filtered, pressed, and the cakes so formed, containing about 75% iodine, are placed in one-ton charges in iron retorts connected with condensers, made of earthenware drain-pipes about 30 in. diameter, placed on a gentle incline. The retorts, after careful luting with clay, are gently fired until the iodine is all driven over. The apparatus is allowed to cool several days, after which the pipes are opened at night, when the temperature is cooler, and the crystallized iodine, 99.6% pure, is shoveled out and packed in 100-lb. barrels, that are afterward sewed in rawhide for transportation. The cost of extraction varies from 1.2 to 1.4d. per ounce; the price has been put up to 9d. The analysis of a sample of mother liquor used for iodine extraction is as follows:

	Tarapaca plant. Grams per litre.
Nitrate of soda	306.61
Chloride of soda	108.45
Nitrate of potash	121.79
Perchlorate of potassium	15.90
Sulphate of magnesia	50.25
Chloride of magnesia	49.97
Iodate of soda	9.73
Sulphate of lime	3.55
Borate of soda	2.83
Boracic acid	21.86
Total	690.94
Water	728.56
Weight of one litre	1419.50

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